# HERITABILITIES AND CORRELATIONS BETWEEN CARCASS AND LIVE ANIMAL TRAITS IN SHEEP

by

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# INTRODUCTION

The consumer demand for meatier retail lamb cuts has placed the pressure on the producer to market an animal which will yield this type of product. The lamb producer should sell his animal when it weighs one hundred pounds or less, yields a 50 pound carcass, and has no more than .25 to .30 inch of fat over the rib-eye muscle. The longissimus dorsi muscle of this carcass should also have at least 2.55 square inches of cross-sectional area at the twelfth rib.

This demand for a meatier lamb may be met by finding one or more live animal characteristics that indicate meatiness in the carcass. Once this feat is accomplished, those traits that are also heritable should be considered in the selection of the breeding sheep that produce the market lamb.

By using subjective scores and objective measurements in the selection of rams and ewes, instead of having to slaughter their offspring to estimate their production potential, progress should be faster and less expensive. Evaluating animals by either sib or progeny slaughter testing is slow and costly because of the rather low reproductive rate and relatively long generation interval in sheep.

This study was initiated to determine the relationship between various live animal traits and carcass traits and to estimate heritability of these traits. The purpose was to also determine the relationship between subjective scores for a ram and production and carcass traits of his lambs, and to determine how these findings may be applied to the selection and breeding of the meatier type lamb.

# REVIEW OF LITERATURE

## Adjusting Data to Standard Basis

Type of birth, sex, and method of rearing influence a lamb's development from birth until it is slaughtered. Correction for variation in these factors must be made before a valid comparison of the various production and carcass characteristics is possible.

Searle (1960) described a simplified herd-level, age correction factor. Warwick and Cartwright (1958) compared the accuracy of six types of weaning weight adjustment procedures. The correlation coefficient between adjusted and actual 120 day weights varied from .99 to .94. Bracketing the 120 day weights by weekly weights and adjusting accordingly resulted in the highest correlation with actual 120 day weights. Regressing weight at an early age on weight at the nearest weigh day resulted in the smallest correlation with actual 120 day weight.

Nelson and Venkatochalam (1949) reported that birth weights of female lambs were 5 per cent less than males, singles were 22 per cent heavier than twins and lambs from mature ewes were 10 per cent heavier than those from two year old ewes. Bogart et al. (1957) found that singles were consistently heavier than twins and rams were heavier than ewe lambs. Regressions of weaning weight on birth weight varied from 2.50 to 5.96 pounds.

Calves that were heavier at birth (Yoa and Cook, 1953) reached weights of 500 pounds and 900 pounds sooner than calves that were lighter at birth. The number of days to weaning was positively and highly correlated with the number of days to final weight of 900 pounds.

Rempel et al. (1959) reported a birth weight advantage of single lambs versus twin lambs of 1.62 pounds and males averaged .55 pound heavier at birth than females. The advantage of being raised as a single rather than as a twin was 8.61 pounds at 100 days of age. There was an advantage of 2.45 pounds for a twin raised as a single rather than as a twin and the advantage of male over female was 3.52 pounds at 100 days of age. Harrington et al. (1958) found that ram lambs were heavier at birth than ewes and as age increased the male's advantage increased until it was 1.9 pounds at 45 days and 5.1 pounds at 135 days. Lambs raised as singles were significantly heavier at all ages than lambs reared as twins. Birth weight was the largest source of variation of any factor measured. It accounted for 33 to 34 per cent of the variation in lamb weights at different ages. Differences in lamb weights due to birth and type of rearing became relatively less important as the lamb grew older.

## Relationship of Live Animal Measurements to Carcass Characteristics

The study of body conformation, carcass characteristics and merit, and their interrelationship is important to the animal breeder. Subjective and objective methods of appraising lambs have been used for some time. These criteria for judging and selecting animals for breeding purposes are thereby aids in genetic improvement. Conformation traits have been used to study the relationship between live animal appraisal scores and carcass characteristics of the meat animal.

The accuracy of measurements taken on sheep (Phillips and Stoeks, 1945) is low due to changes of position by the animal and errors resulting from the operator's inability to properly locate the point of reference. The

most accurate measurements, those which were more repeatable, were height of withers, length from mid-front scapula to pin bones, width of shoulder, depth of chest, depth of middle and circumference of chest.

Knight (1959) found significant correlations between length of foreleg and loin-eye width, depth, and area to be .63, -.46, and .66, respectively. There was a positive relationship between circumference of the leg and the width of the longissimus dorsi muscle. Matthews (1959) found that length of foreleg and circumference of right forecannon were positively associated with traits indicating leanness and negatively associated with traits indicating fat. Henneman (1942) reported that long shanked lambs had the highest percentage of leg. This indicates that a lamb which is long in the cannon and tibia, probably has a long femur, thus increasing the length of the muscle.

Width of shoulder, width behind the shoulder and circumference of heart (Orme _et al._, 1961) accounted for 30 to 40 per cent of the variation in the lean body mass of the carcasses. Botkins _et al._ (1960) reported that live leg width was highly significantly related with carcass leg area and total carcass lean with correlations of .83 and .73 respectively. Terrill _et al._ (1961) found that live leg width and carcass leg width were highly correlated, .82, and each was relatively highly correlated with other carcass measurements indicating meatiness. Carcass leg width was more highly correlated with carcass measurements indicating meatiness. However, leg width in the live animal appears to have possible merit as a criterion for live lamb selection.

Bailey _et al._ (1961) reported that width of gigots and circumference of thigh, which were highly correlated with each other, .83, were closely

associated with loin-eye area, .59, .42, and .52, .60 respectively for two different years.

In beef cattle (Orme et al., 1959) found that height at rump was highly related to carcass length and accounted for approximately 64 per cent of the variation in carcass length. Circumference of body at foreflank, hind flank and middle were responsible for approximately 26 per cent of the variation in rib-eye area. With body weight held constant circumference of body at foreflank accounted for 81 per cent of the variation in rib-eye area. Width of rump and circumference of leg above the hock were correlated with rib-eye area. 35 and .36, respectively. Yao and Cook (1953) correlated body height, width, length, head width and length, and body circumference measurements with each other and with slaughter grade, carcass grade and dressing per cent in beef cattle. Length of body was highly significantly correlated with width of loin and width of hip, .30 and .52 respectively. Body circumference at foreflank, navel and rear flank were significantly correlated with carcass grade, .22, .27, and .29, respectively.

Foote et al. (1961) concluded that no relationships between live animal measurements and carcass merit have been found that appear high enough to be of predictive value in estimating carcass quality from traits in the live animal. Live weight and metatarsus length were most closely correlated with loin-eye area, .32 and .34, respectively. The correlation between subjective scores or eye appraisal of loin-eye area and actual area was .33. Botkins et al. (1960) found that cannon bone circumference was highly significantly correlated with leg area, rib-eye area and total lean in a half carcass, .80, .69 and .80, respectively. Terrill et al. (1961)

used feeder type lambs in studying live animal measurements in relationship to carcass measurements and characteristics. The correlation between loin-eye area and circumference of cannon bone became zero when carcass weight was held constant statistically.

Orme et al. (1961) found that live lamb weight and chilled carcass weight were the best indicators of carcass leanness, the correlations were .89 and .89 respectively. Matthews (1959) reported that when live weight was held constant, there was a significant positive relationship between live weight and longissimus dorsi area, r = .53, and a negative relationship between live weight and fat depth at the twelfth rib, r = -.33. Holding carcass weight constant was of less importance in determining loin-eye area in carcasses (Bailey et al., 1961) from older lambs than younger lambs. This may have been due to more fat on older lambs.

Bratzler and Margerum (1953) found weight, body length, back fat thickness, and dressing per cent to be major factors determining the yield of preferred cuts in swine.

Matthews (1959) found that length of rump was significantly related to per cent leg, r = .35, and as length of rump increased per cent loin decreased. This is not in agreement with Henneman (1942), who reported that lambs that were long from the hooks to pins had a lower percentage of leg. Practically all live animal characteristics (Matthews, 1959) correlated with per cent leg and per cent loin were opposite in their effect. He also found that width of loin was positively associated with muscling measurements in the carcass, whereas the per cent loin was positively associated with fatness.

Ross et al. (1961) reported significant correlations between weight

of leg and loin-eye area, .70 and .57, for singles and twins respectively.

### Relationship of Scores and Measurements to Production Traits

Cole et al. (1942) found that average width of shoulder, rib, loin and rump of lambs was highly correlated with average daily gain, .97. This is in agreement with Henneman (1942) who reported that thickness of fat over the twelfth rib was not significantly correlated with average daily gain, indicating that fat was not making up width. Length of leg (Cole et al., 1942) was of no value in estimating daily gain. Henneman (1942) reported width of rack and depth of forerib and the combination of the two were significantly correlated with average daily gain, .60, .45, and .67, respectively. These correlations indicate that constitutional developments are indicators of rapid gain. Cole et al. (1942) agreed with this fact and demonstrated that the sum of the depth of forerib, width of rack and grams of bone per centimeter of shank was correlated with average daily gain, .76, thus showing that rugged larger-boned lambs gain faster.

Henneman (1942) reported that the ratios of length of body plus average length of leg to average width, led to correlations significant at (P .01). This indicated that lambs wide in proportion to their length gained more rapidly.

Bailey et al. (1961) found a correlation of .56 between 120 day weight and loin-eye area and showed that loin-eye area could be predicted as accurately by using the simple regression of loin-eye area on weaning weight or carcass weight as by an combination of the variables they studied.

Relationship Between Carcass Traits

Matthews (1959) reported that carcass grade was positively correlated with depth of fat, .61, marbling, .60, and with carcass length, -.99. Carcass grade was significantly negatively correlated with width of longissimus dorsi -.58 and positively correlated with depth of longissimus dorsi .29. Carcass grade was positively associated with per cent loin and rack, but was negatively associated with area of longissimus dorsi, per cent leg, and per cent shoulder. Depth of back fat was positively correlated with marbling, .60, per cent loin, .54, and per cent rack, .54. Back fat depth was negatively associated with per cent shoulder, $r = -.46$, and per cent lean in rack, $r = -.58$. Marbling was significantly correlated with per cent fat in rack, .68, and ether extract of longissimus dorsi $r = .60$.

Hankins (1947) found that the skeletal growth in lambs occurs first, muscle next, and fat last. Fat is the most expensive of the three to produce. The weight of the rib cut (rack) was very closely related to that of the fat in the dressed carcass. Hankins and Titos (1939) reported that the amount of fat in sheep carcasses increases in certain cuts faster than in others as the carcass becomes heavier. An increase in carcass weight from 22 to 48 pounds produced an increase in per cent rib and loin and a decrease in per cent leg, shoulder, neck and breast. As per cent fat in the carcass approached 22, the per cent fat in the leg fell below all the other cuts. At 28 per cent fat in the carcass the rib contained the highest per cent fat and at 37 per cent fat in the carcass there was a difference of 30 per cent between per cent fat in the rib, the fattest cut, and per cent fat in the leg, the leanest cut. Fat was deposited in

the loin and rack earlier than in the other carcass cuts. There was a positive relationship between the fatness and per cent loin and rack. Rempel et al. (1962) found that per cent loin and backfat depth were positively associated with fatness.

Hankins (1947) reported a high positive correlation between fat in the rib cut (rack) and the fat content of the carcass. The lean content of the rib cut was highly correlated with muscle content of the carcass. The weight of leg was the second best indicator of total lean in the carcass. The bone in the rib cut was valuable for predicting total bone in the carcass. From Hankin's (1947) study it appears that the fat, muscle and bone content of all wholesale cuts can be estimated with satisfactory accuracy from the corresponding components of the rib cuts, with the exception of muscle content of neck, shoulder and breast. This is in agreement with Matthews (1959).

Stanley et al. (1961) reported correlations between rack meatiness score as determined by a photographic grid and carcass rib angle, area of leg and area of rib-eye that were significant; .39, .29, and .37, respectively. The best indicators of total lean in the rack reported by Stanley et al. (1961) were leg area and rib-eye area. Highly significant correlations of .71 and .65, respectively, were found. Botkins et al. (1960) found a close relationship between lean in one leg and total lean in half of the carcass, $r = .99$. This agrees with results of Palsson (1939) who reported a high relationship between the total lean and cross sectional area of lean in the leg, $r = .92$. Leg area was more closely related to total lean in the carcass than was rib-eye area, with correlations of .91 and .53, respectively. A significant correlation was found between leg

area and rib-eye area, .73.

Orme et al. (1961) found highly significant simple correlations between separable carcass lean and weight of the longissimus dorsi, biceps femoris, semitendinosus and sirloin tip muscle, .86, .83, .77, and .90, respectively, but no correction for carcass weight was reported.

Zinn (1961) reported that percentage of retail trimmed rack, loin, sirloin, and leg were more closely related to rib-eye area, leg area, and per cent retail fat trim than were percentages of wholesale rack, loin and leg. Rempel et al. (1961) found a significant negative relationship between per cent untrimmed leg and untrimmed loin, .61. A significant relationship was reported between per cent leg and loin-eye area, $r = .48$ but the relationship between per cent leg and dressing per cent was negative.

Zinn (1961) reported that carcasses from ram lambs had the least amount of fat, those from wethers were intermediate, and carcasses from ewe lambs had the most fat when slaughtered at the same weight.

Palsson (1939) reported a larger late maturing lamb, at the same weight as a small early maturing one, though having most external measurements higher than the latter, may have less muscling due to the larger development of the skeleton. One of the main factors affecting the muscle to bone ratio according to Palsson (1939) was the thickness of muscle cover. The difference between the leg length and the length of tibia and torus indicated the amount of development of the musculature around the femurs and between the legs. The smaller this difference, the thicker the muscle cover. Width of loin-eye muscle was correlated with weight of total lean in the carcass, $r = .67$, (P .05). This is an early developing character and thickness or depth is a later maturing one according to

Palsson (1939).

## Objective Techniques for Estimating Carcass Characteristics

Few workers have used objective techniques for predicting carcass characteristics from traits in the lamb. More work of this nature has been done with swine.

The live probe in swine has been evaluated by Hazel and Kline (1952); DePape and Whatley (1956); and Hertzer _et al._ (1956). The probe was a reliable indicator of backfat thickness, percentage of lean cuts, and total carcass leanness. Holland and Hazel (1958) found the probe to be highly accurate in appraising leanness in hogs as measured by per cent lean cuts.

The live probe technique in lambs as described by Matthews _et al._ (1960) has been used by several workers. Stauffer _et al._ (1958) reported significant correlations of live probe with rib-eye area and back fat thickness of .42 and .58 respectively. Matthews _et al._ (1960) reported a correlation of .59 between live animal probe depth of the longissimus dorsi and carcass rib-eye area and a correlation of .57 between live animal probe depth of fat and actual fat depth on the carcass.

Zobrisky _et al._ (1961) using an ultrasonic device obtained a highly significant correlation between estimated rib-eye area and actual rib-eye area measured from tracings. The estimate of back fat thickness was closely associated with actual back fat thickness. Campbell _et al._ (1959) using an ultrasonic technique found correlations between estimated and actual area of the cross section of longissimus dorsi of .62 and .44 for two different groups of lambs.

## Heritability of Carcass Traits

Ross et al. (1961) found highly significant differences among ram progeny groups for untrimmed leg (P .05), untrimmed shoulder (P .01) and trimmed shoulder (P .05). Sire effects were significant (P .05) for birth weight, weaning weight and wool weight. Sire effects on rate of gain were not significant.

Considerable variation in heritability estimates of some traits exist in the literature. For example, heritabilities reported for weaning weight in lambs have varied from 7 to 56 per cent. However, very few heritability studies concerning objective measurements and carcass traits in sheep have been reported.

Chapman and Lush (1932); Blackwell and Henderson (1955); and Nelson and Venkatochalam (1949) reported heritability estimates of birth weight in lambs as .61, .30, and .41, respectively. Givens et al. (1960); Shelton et al. (1954) reported estimates of 18 and 58 per cent for average daily gain in lambs, respectively. Estimates of heritability of weaning weight, .56, .07, .07, and .24, were reported by Warwick and Cartwright (1957); Blackwell and Henderson (1955); Givens et al., (1960); and Nelson and Venkatochalm (1949). Shelton et al. (1954); Hazel and Terrill, (1945) and Kyle, (1951) reported heritability estimates of conformation score of .20, .06, and .20, respectively. Givens et al. (1960) reported an estimate of .12 for market grade.

In cattle Dawson et al. (1955) reported the following heritability estimates: gain from weaning to 500 pounds, .45; birth weight, .50; average daily gain, .19; dressing per cent, .69; and carcass grade, .67. Kieffer et al. (1958) estimated heritability of the rib-eye area to be

52 per cent in cattle.

## MATERIALS AND METHODS

The lambs used in this study were produced in 1959-60 and 1960-61 by 100 typical western ewes obtained as yearlings in the spring of 1959 from Del Rio, Texas.

The ewes were randomly divided into 10 equal groups, and mated to unrelated Hampshire rams. One ram was randomly assigned to each group of ewes. In 1959 one ram was sterile so the ewes in his group were randomly assigned to the other nine groups. These nine rams sired the 77 lambs included in this study.

In 1960, Hampshire rams were again used on the same ewes and 99 lambs resulted from these matings. The breeding season was from June 1 to August 15 each year and "clean-up" rams were then turned with the ewes. Any lambs sired after August 15 were by the "clean-up" rams, hence the relatively small experimental lamb crop.

The ewes and lambs were maintained in dry lots from the time the lambs were born until the lambs were slaughtered. The lambs were fed a complete pelleted creep ration and slaughtered when their unshorn feedlot weights were from 95 to 100 pounds. They were then shorn and objective measurements were taken. The lambs were held off feed approximately 12 hours prior to slaughter.

The rams were weighed and scored just after the breeding season was over, August 15 each year. A committee of 5 men scored each ram for muscling, length of legs, general type and size of leg. The rams used to produce the 1960-61 lambs were probed as described by Matthews *et al.* (1961),

to estimate depth of the longissimus dorsi muscle. The probe depth was adjusted for weight of the ram by regression analysis. These scores and measurements were correlated with the average production traits and carcass characteristics of their lambs.

Birth weight, market age, average daily gain, slaughter weight, and cold carcass weight were corrected by adjusting for type of birth (single or twin) and sex.

The correction factor used to adjust each characteristic was derived by using the multiplicative correction method described by Searle (1960).

$$ZM = \text{male birth weight}$$

$$ZY = \text{female birth weight}$$

$$E(ZM) = fy\ zy$$

$$fy = \frac{zm}{zy} = \text{correction factor}$$

To adjust a female birth weight to that of a male, the female birth weight was multiplied by the correction factor.

The relationship among live animal scores and measurements, between live measurements and carcass characteristics were analyzed by obtaining the simple correlation coefficients. When the correlation for the two years was not statistically different, (Snedecor, 1946) the weighted average of the two correlations for the same two variables is reported.

The lambs were shorn before live evaluations were made so that anatomical reference points could be more easily palpated and measured.

Objective methods employed to evaluate the live lamb were as follows:

Depth of the longissimus dorsi muscle was estimated by using a probe technique as described by Matthews _et al._ (1960-61). This technique was used only on the lambs produced in 1960-61.

The following measurements were taken with large metal calipers and recorded to the nearest tenth of an inch:

Width of the loin was measured as the distance between the lateral extremities of the transverse process of the second lumbar vertebra. Depth of heart was measured from the dorsal vertebral process to the ventral surface of the sternum immediately behind the front leg. Length of body was measured from the lateral tuberosities of the right humerus to the tuber ischii on the right side. Width of hind leg was measured as the distance between the lateral extremities of the gigots on both rear legs. Length of rump was measured from the anterior point of the tuber coxae to the posterior point of the tuber ishii.

The following measurements were taken on the right side of the body with a string and measured on a metal ruler to the nearest tenth of an inch: Length of forecannon was measured as the distance between the proximal and distal ends of the metacarpus. Circumference of forecannon was measured at a point equidistant from the ends of the metacarpus at right angles to the axis of the cannon bone. Circumference of the hind leg (pin to pin) was measured from the posterior point of the tuber ischii passing ventrally between the legs at their junction and returning to the initial point via the rear flank immediately anterior to the patella. Circumference of the leg at the patella was measured horizontally around the leg at the patella to the longitudinal axis of the body. Length from hook to leg insertion was measured from the tuber coxae to the point where the leg muscle tapered toward the hock. Length of coupling was measured as the distance between the anterior point of the tuber coxae and the dorsal posterior point of the last rib.

These lambs were slaughtered by the University Meats Personnel and the carcasses were also used in a lamb quality study.

Cold carcass weight was obtained after a 48 hour chill.

Six measurements were taken on the carcass after it had been in the cooler for 24 hours. Depth of heart, length of right forecannon, circumference right forecannon, length of body, width of hind legs, and width of loin were all measured by using the same reference points as were used in making the same measurements on the live lamb. All measurements were taken to the nearest tenth of an inch.

Carcass grade was determined by an official of the U.S.D.A. Federal Grading Service and was recorded to the nearest third of a grade. The grader subjectively scored each carcass for feathering, degree of marbling, firmness and color of lean before the carcass was broken. After the carcasses were broken between the twelfth and thirteenth ribs he scored each for actual marbling at the twelfth rib and this score was used as the marbling score in the analysis.

Cross-sectional area of the longissimus dorsi muscle was measured from the tracing made at the twelfth rib by using the compensating Polar Planimeter. Fat depth at the twelfth rib was measured to the nearest tenth of an inch from the tracing.

Weights of leg, loin, rack, shoulder, breast, and kidney knob were obtained after each carcass was separated into the wholesale cuts in accordance with the procedure recommended by the Lamb Evaluation Committee of the Reciprocal Meats Conference (1953).

In accordance with the recommendation of Hankins (1947) the wholesale rack was selected to study the weight of tissue composition. The weights

of physically separable fat, lean, and bone in the rack were recorded to the nearest gram.

The ether extract content of the longissimus dorsi muscle and the intercostal tissue were determined (a modified Babcock method) from a random sample of the ground tissue of each. The ether extract content was recorded as per cent of the fresh sample.

Significance of sire effect on the lamb and carcass traits studied was determined by analysis of variance.

Hertability estimates based on paternal half-sib correlations were determined for all traits studied.

## RESULTS AND DISCUSSION

### Relationship of Scores and Traits of Rams

Correlation coefficients between weight, depth of longissimus dorsi muscle and subjective scores of rams are presented in Table 1.

Weight of ram was highly significantly correlated with all ram scores and measurements. It was most highly correlated with depth of longissimus dorsi probe, .99, and general type, .84.

Size of bone was highly significantly correlated with length of leg, .90, and general type, .78. In scoring the ram for length of leg, the higher the score the shorter the leg. Estimated muscling score was highly significantly correlated with general type, .87, and size of rear leg, .85. General type was also highly significantly correlated with size of rear leg, .79, and loin probe depth, (corrected for weight of ram) .84.

These relationships indicate that in selection for general type in rams most emphasis is probably placed on muscling, size of bone, size of

Table 1. Correlation coefficients between ram weight, depth of longissimus dorsi and subjective scores.

| | S.B. | M.S. | L.L. | G.T.S. | S.L. | D.L.D. |
|---|---|---|---|---|---|---|
| R.W. | .67 | .62 | .55 | .84 | .53 | .99 |
| S.B. | | .68 | .90 | .78 | .62 | .63 |
| M.S. | | | .50 | .87 | .85 | .64 |
| L.L. | | | | .60 | .43 | .43 |
| G.T.S. | | | | | .79 | .84 |
| S.L. | | | | | | .68 |

Correlation of .46 is significant at .05 level.

Correlation of .57 is significant at .01 level.

CODE:

R.W.-----Ram weight

S.B.------Size of bone

M.S.------Muscling score

L.L.------Length of leg

G.T.S.----General type score

S.L.------Size of leg

D.L.D.----Depth of longissimus dorsi

leg, and weight of the ram.

The relationship between estimated muscling and size of rear leg indicated that depth of twist and thickness of leg are the most useful indicators of estimated muscling in rams. The significant positive relationship of size of bone and length of leg indicated that a short legged ram had more bone than a leggier ram.

## Relationship of Ram Scores and Measurements With Production and Carcass Traits of Their Lambs

Simple correlation coefficients between ram weight, corrected depth of longissimus dorsi probe of the rams in 1960 and subjective scores of the rams and production and carcass traits of their lambs are presented in Table 2. The production and carcass traits used in the correlations were averages of each trait for all lambs sired by each ram.

The only traits of the ram that were significantly correlated with lamb traits were length of leg, size of rear leg and depth of longissimus dorsi muscle probe. Length of leg in the ram (the shorter legged rams were given the highest score) was positively significantly correlated with loin-eye width, .48, and negatively significantly correlated with loin-eye depth in the carcass, -.50, indicating that shorter legged rams tend to sire lambs that had wide but shallow loin eyes. Loin-eye area was positively related to short legged ram .35. Leg weight of lamb carcasses was negatively related to length of leg of ram. Size of bone was positively related to loin-eye area and depth in the carcass, the correlations being .20 and .35, respectively. Size of leg in the sire was negatively significantly related to birth weight, $r = -.55$, and negatively correlated to average daily gain, -.34, weight of shoulder, -.23, and weight of rack, -.24, in the lambs.

Probe depth of longissimus dorsi in the rams in 1960-61 was highly significantly correlated with market age, -.60, and carcass grade, -.59, in the lambs. Probe depth in the ram was positively correlated with loin-eye area, .39, and significantly related to weight of shoulder, $r = -.50$, in the carcasses of his lambs. Weight of the loin in the lambs was positively

CODE
(Table 2)

| | |
|---|---|
| B.W.------Birth weight | R.W.------Ram weight |
| M.A.------Market age | S.B.------Size of bone |
| A.D.G.---Average daily gain | M.S.------Muscling score |
| Le.A.----Loin-eye area | L.L.------Length of leg |
| Le.D.----Loin-eye depth | G.T.S.---General type score |
| Le.W.----Loin-eye width | S.L.------Size of leg |
| C.G.------Carcass grade | D.L.D.---Depth of longissimus dorsi |
| B.Wt.----Breast weight | |
| S.Wt.----Shoulder weight | |
| R.Wt.----Rack weight | |
| L.Wt.----Loin weight | |
| Le.Wt.---Leg weight | |
| L.R.------Lean in rack | |
| F.R.------Fat in rack | |
| B.R.------Bone in rack | |

Table 2. Simple correlation coefficient between weight, probe depth of longissimus dorsi and subjective scores in the rams and production and carcass traits of their lambs.

| | R.W. | S.B. | M.S. | L.L. | G.T.S. | S.L. | D.L.D. |
|---|---|---|---|---|---|---|---|
| B.W. | .02 | -.29 | -.50 | -.19 | -.37 | -.55 | .31 |
| M.A. | -.19 | -.02 | .08 | -.06 | -.07 | .37 | -.60 |
| A.D.G. | .19 | .14 | -.04 | .19 | .09 | -.34 | .24 |
| Le.A. | .25 | .20 | -.22 | .35 | .01 | -.10 | .39 |
| Le.D. | .30 | .35 | -.12 | .50 | .20 | -.13 | .25 |
| Le.W. | .03 | .24 | -.16 | .48 | -.18 | .28 | |
| C.G. | -.30 | -.04 | -.10 | -.12 | -.20 | .27 | -.59 |
| B.Wt. | -.00 | .10 | -.30 | .22 | -.15 | -.30 | .02 |
| S.Wt. | -.05 | -.05 | -.25 | .02 | -.12 | -.23 | -.50 |
| R.Wt. | -.00 | -.11 | -.05 | .03 | -.11 | -.24 | -.04 |
| L.Wt. | .20 | -.12 | -.08 | -.08 | .03 | .24 | .52 |
| Le.Wt. | .00 | -.39 | -.01 | -.38 | -.07 | .01 | -.01 |
| L.R. | -.13 | -.23 | -.18 | -.12 | -.30 | -.20 | -.08 |
| F.R. | .12 | -.08 | .13 | -.05 | .07 | .17 | .09 |
| B.R. | .06 | -.02 | -.17 | .09 | -.11 | -.15 | .37 |

Correlation of .46 is significant at .05 level.

Correlation of .57 is significant at .01 level.

correlated with depth of loin probe in the sire, .52.

The importance of finding traits in the ram that reflect production or carcass characteristics in their lambs becomes very clear by observing the correlations listed in Table 2. These correlations are so low that they offer little aid in the selection of rams. These relationships indicate that lambs sired by shorter legged rams tend to have larger loin-eye areas but have smaller legs. Size of leg in the ram, as indicated in Table 1, was positively related with muscling score in the ram. If rams with larger legs of mutton are selected, birth weight of their lambs will be smaller and these lambs will have smaller average daily gains. This is not the kind of relationship that faborably impresses the sheep producer. An explanation for this may be that the smaller type rams appeared to have larger legs and they sired lambs that were smaller at birth and gained slower.

The probe of the longissimus dorsi muscle depth could be used in the selection of rams. However, the negative relationship between depth of probe and market age is very important in regard to economy of production. The younger lambs that reached market weight sooner had a slightly lower carcass grade due to maturity and quality characteristics.

All ram traits such as ram weight, size of bone, length of leg, were non-significantly negatively related to grams of lean in the rack of carcasses produced by their lambs (Table 2).

Relationship Between Production Traits in Lambs
and Their Carcass Characteristics

Correlation coefficients between production traits and carcass characteristics of lambs are shown in Table 3. These correlations are all weighted averages for the same variables during the two years. The blank spaces in the tables are for correlations, between the same two variables, that were statistically different doing the two years.

Throughout the rest of this paper traits for live lambs will be referred to as lamb traits and lamb carcass traits as carcass traits.

Degree of marbling and carcass grade were significantly correlated with birth weight, -.19, and -.18, respectively. Degree of marbling was significantly correlated with carcass grade, .37, as shown in Table 8. Estimates of degree of marbling are used in grading carcasses.

Birth weight was significantly correlated with grams of lean in rack, .20, and grams of bone in rack, .34.

Average daily gain was significantly related to birth weight, r = .47, and also to grams of lean and bone in the rack, with correlations of .20 and .28, respectively.

Weights of leg and shoulder were also significantly correlated with average daily gain, .16 and .20, respectively. Weight of shoulder, leg, and grams of lean in the rack were all positively associated with total lean in the carcass as is presented in Table 8.

Cole et al. (1942) and Henneman (1942) both reported significant correlations between average daily gain and width and depth measurements of the lamb and carcass.

Market age was significantly correlated with feathering and marbling,

CODE
(Table 3)

Fea.----Feathering

Mar.----Marbling

C.G.----Carcass grade

Wt.S.---Weight of shoulder

Wt.R.---Weight of rack

Wt.L.---Weight of loin

Wt.Le.--Weight of leg

Le.A.---Loin-eye area

B.F.----Back fat

L.R.----Lean in rack

F.R.----Fat in rack

B.R.----Bone in rack

B.W.-----Birth weight

A.D.G.---Average daily gain

M.A.-----Market age

M.W.-----Market weight

Table 3. Weighted average correlation coefficients between birth weight, market weight, average daily gain, market age and carcass characteristics.

| | B.W. | A.D.G. | M.A. | M.W. |
|---|---|---|---|---|
| Fea. | -.07 | | .27 | |
| Mar. | -.19 | | .16 | |
| C.G. | -.18 | | | .05 |
| Wt. S. | .12 | .16 | | .25 |
| Wt.R. | | | | .12 |
| Wt.L. | | | | .27 |
| Wt.Le. | | .20 | | .23 |
| Le.A. | -.12 | | .07 | |
| B.F. | | | | |
| L.R. | .20 | .20 | | .03 |
| F.R. | | .13 | | |
| B.R. | .34 | .28 | | |
| B.W. | | .47 | -.54 | .31 |
| A.D.G. | | | .91 | |

Correlation of .15 is significant at .05 level.

Correlation of .20 is significant at .01 level.

.27 and .16, respectively; indicating that older more mature lambs had more feathering and marbling than younger lambs at the same weight. Market age was negatively correlated with birth weight, -.54 (P .05). The producer desires that his lambs reach market weight as soon as possible and with this negative relationship between birth weight and market age, raises the question as to how heavy should lambs be at birth, as heavier birth weight might increase lambing difficulty.

Bailey _et al._ (1961) indicated that loin-eye area could be predicted fairly accurately by using the simple regression of loin-eye area on weaning weight.

Significant positive correlations were obtained between market weight and weight of shoulder, loin, leg, and grams of bone in the rack. This relationship was expected since these carcass traits largely make up market weight. Market weights (ranging from 95 to 100 pounds) were the weights of the lambs at the barn just before they were sheared.

These relationships indicated that heavier lambs at birth gained faster and reached market weight sooner. The lambs were less mature and the carcasses contained less feathering and marbling; consequently the carcass grades were lower. The positive relationship between birth weight and average daily gain and those carcass traits that are related to leanness and bone rather than fat indicated that up to a weight of 100 pounds, gain was primarily due to growth rather than the production of fat.

## Relationship Between Live Lamb Measurements

Correlation coefficients between lamb measurements are presented in Table 4. Length of rump, from hook to pin, was significantly correlated with several other measurements: depth of heart, .27; length of forecannon, .20; circumference of forecannon, .21; length of body, .26; circumference of rear leg, .22; circumference of rear stifle .22, width of rear leg, .22; and length from hook to leg muscle insertion, .27. Most of these traits are associated with skeletal growth. Longer bodied lambs with thicker legs also had longer rumps. Weight of leg increased as length of rump increased, as shown in Table 5. A positive correlation between length of leg and length of rump indicates that the more upstanding lambs tend to have a larger longer body.

Length of right forecannon was significantly correlated with length of body, .22, and length of body was significantly related to circumference of right forecannon, r = .26. The former correlation supports the earlier statement that longer legged lambs had longer bodies.

Circumference of rear leg was significantly correlated to circumference of stifle, .22; width of leg, .15; and length from hook to leg insertion, .23. Longissimus dorsi muscle probe was not significantly correlated with any live animal measurement.

## Relationship Between Lamb Measurements and Carcass Characteristics

Only a few correlations between lamb measurements and carcass characteristics, even those that were statistically significant, were of sufficient magnitude to be effectively employed in a selection program. Correlations

CODE
(Table 4)

D.H.——Depth of heart

L.F.——Length right forecannon

C.F.——Circumference right forecannon

L.B.——Length of body

L.C.——Length coupling

L.R.——Length rump

W.L.——Width second lumbar

C.R.L.——Circumference rear leg

C.R.S.——Circumference rear stifle

W.R.L.——Width rear legs

L.H.L.——Length hook to leg insertion

L.P.——Longissimus dorsi probe

Table 4. Weighted average correlation coefficients between live lamb measurements.

| | D.H. | L.F. | C.F. | L.B. | L.C. | L.R. | W.L. | C.R.L. | C.R.S. | W.R.L. | L.H.L. | L.P. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| D.H. | | .14 | .07 | | | .27 | | | .03 | | | .05 |
| L.F. | | | .11 | .22 | .11 | .20 | -.08 | | .09 | | | .03 |
| C.F. | | | | .26 | | .21 | | | .11 | | | -.04 |
| L.B. | | | | | | .26 | | .14 | | | | .10 |
| L.C. | | | | | | | .06 | | | | | -.05 |
| L.R. | | | | | | | | | .22 | .22 | .27 | .23 |
| W.L. | | | | | | | | .39 | | | | .19 |
| C.R.L. | | | | | | | | | .22 | .15 | .23 | .22 |
| C.R.S. | | | | | | | | | | | .13 | .00 |
| W.R.L. | | | | | | | | | | | .14 | -.07 |
| L.H.L. | | | | | | | | | | | | -.05 |

Correlation of .15 is significant at .05 level.

Correlation of .20 is significant at .01 level.

between lamb measurements and carcass characteristics are presented in Table 5.

Depth of heart was not significantly correlated with any of the carcass characteristics studied. Length of forecannon was significantly related to only the weight of bone in the rack, r = .28, and was positively correlated to weight of leg, r = .07, and negatively related to back fat thickness, r = -.12, as measured from tracings.

Circumference of right forecannon was significantly correlated with weight of leg, .23. This was in agreement with the results reported by Botkins (1960). Also, circumference of right forecannon was significantly correlated with lean in rack, .27, bone in rack, .39, and was negatively associated with back fat thickness and grams of fat in the rack. Matthews (1959) found length of foreleg and circumference of right forecannon to be positively associated with traits indicating leanness and negatively associated with traits indicating fat. Circumference of right forecannon was significantly correlated with carcass grade, -.29.

Length of body was significantly negatively related to carcass grade, -.18, indicating shorter bodied (possibly more compact) lambs yielded higher grading carcasses. Also weights of loin and of leg were significantly correlated with length of body, .17, and .22, respectively. Yao and Cook (1953) reported that length of body in cattle was highly significantly correlated with length of rump, .28. This may be an indication that lambs with more length yield relatively more valuable cuts of the carcass. Length of body was significantly correlated with loin-eye area, .16, and grams of bone in the rack, .23.

Length of loin was significantly correlated with weight of loin, .22,

CODE
(Table 5)

C.G.——Carcass grade

Wt.B.——Weight of breast

Wt.S.——Weight of shoulder

Wt.R.——Weight of rack

Wt.L.——Weight of loin

Wt.Le.——Weight of leg

S.W.C.——Sum wholesale cuts

Le.A.——Loin-eye area

B.F.——Back fat

L.I.R.——Lean in rack

F.R.——Fat in rack

B.R.——Bone in rack

D.H.——Depth of heart

L.F.——Length right forecannon

C.F.——Circumference right forecannon

L.B.——Length body

L.C.——Length coupling

L.R.——Length rump

W.L.——Width second lumbar

C.H.L.——Circumference hind leg

C.H.S.——Circumference hind stifle

W.H.L.——Width hind leg

L.H.L.——Length from hook to leg muscle insertion

M.P.——Longissimus dorsi muscle probe

Table 5. Weighted average correlation coefficients between lamb measurements and carcass characteristics.

| | Lamb Measurements | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | D.H. | L.F. | C.F. | L.B. | L.C. | L.R. | W.L. | C.H.L. | C.H.S. | W.H.L. | L.H.L. | L.P. |
| C.G. | | | -.29 | -.18 | | | .17 | .16 | | .18 | .17 | .14 |
| Wt.B. | .05 | | | .04 | .07 | .17 | .19 | .05 | -.08 | | .28 | .05 |
| Wt.S. | .13 | | .15 | | | | .15 | | | .11 | .11 | .12 |
| Wt.R. | | | | .10 | .11 | .09 | .30 | | .10 | | | -.06 |
| Wt.L. | .07 | | -.08 | .17 | .22 | .16 | .45 | | -.14 | -.14 | | .19 |
| Wt.Le. | .11 | .12 | .23 | .22 | | .51 | .15 | .34 | .14 | .13 | .20 | .06 |
| S.W.C. | .09 | | .13 | .16 | .10 | .33 | .40 | .09 | | | .18 | |
| Le.A. | | | .12 | .16 | | .17 | .14 | .09 | .09 | | .01 | .00 |
| B.F. | | -.12 | -.10 | | | | .23 | -.07 | -.18 | -.07 | .04 | -.05 |
| L.I.R. | | .10 | .27 | .14 | .04 | .19 | .04 | .09 | .18 | | | -.09 |
| F.R. | | | -.12 | | .11 | | .34 | -.12 | -.12 | | | -.04 |
| B.R. | | .28 | .39 | .23 | | .18 | | .21 | | | | -.20 |

Correlation of .15 is significant at .05 level.

Correlation of .20 is significant at .01 level.

and was positively correlated with weight of rack and grams of fat in the rack. All three of these carcass traits were related to fat in the carcass.

Length of rump was significantly correlated with weight of breast, .17; weight of leg, .51; weight of loin, .16; and total weight of all the wholesale cuts, .33. This agreed with results reported by Matthews (1959). Weight of leg was significantly related to loin-eye area, $r = .39$, and grams of lean in rack, $r = .39$, Table 8. Length of rump was also significantly correlated with loin-eye area, .17, grams of lean in the rack, .19, and grams of bone in the rack, .18. Length of rump may possibly be one of the most valuable live animal measurements for predicting carcass merit.

Width of the second lumbar vertebra, live lamb estimate of width of loin, was significantly related to most of the carcass characteristics. However, it was more highly correlated to those carcass characteristics indicating fat such as weight of breast, .19; weight of rack, .30, weight of loin, .45, back fat thickness, .23; and grams of fat in the rack, .34.

Width at the second lumbar vertebra was significantly correlated with carcass grade, .17. Carcass grade was significantly related to weight of loin, $r = .30$ (Table 8). Weight of leg and loin-eye area were also significantly related to width of second lumbar vertebra, with correlations of .15 and .14, respectively.

Circumference of hind leg was significantly correlated with carcass grade, .16, and weight of leg, .34. Circumference of hind leg was also positively associated with grams of bone in the rack and negatively related to fat in the rack.

Circumference of the stifle at the patella was significantly related

to grams of lean in the rack, r = .18 and negatively related to back fat thickness, r = -.18 (P .05). There was a negative relationship between circumference of stifle and grams of fat in the rack, weight of the loin and weight of the breast.

Circumference of hind leg and of stifle were positively associated with carcass traits indicating meatiness and negatively associated with those carcass traits indicating fat.

Width of hind leg was significantly correlated with carcass grade, .18, and was negatively related to eight of loin and back fat thickness. There was a positive relationship between weight of leg and width of hind leg. Botkins et al. (1960) found leg width had a highly significant relationship to leg area, r = .83.

Length from hook to leg muscle insertion was measured to determine the degree of bulge on the outside of the leg of the lamb. This measurement was significantly correlated with weight of leg, .20; weight of breast, .28; and carcass grade, .17.

## Relationship Between Live Animal and Carcass Measurements

Correlation coefficients between lamb measurements and carcass measurements are presented in Table 6.

Depth of heart taken on the lamb was not significantly correlated with any of the carcass measurements. Depth of heart on the carcass was significantly positively correlated with length of the right forecannon, .23; circumference of right forecannon, .24; length of rump, .27; and length from hook to leg muscle insertion, .27, on the lamb. These lamb measurements are all associated with skeletal growth as was depth of heart in the carcass.

Table 6. Weighted average correlation coefficients between live animal and carcass measurements.

| Live animal traits | D.H. | L.F. | C.F. | L.B. | W.H.L. | W.L. |
|---|---|---|---|---|---|---|
| | | | Carcass Measurements | | | |
| D.H. | .04 | .11 | -.03 | .10 | .08 | -.04 |
| L.F. | .23 | .29 | .09 | .13 | .15 | .16 |
| C.F. | .24 | .12 | .62 | .03 | .17 | -.15 |
| L.B. | .16 | .19 | .24 | .12 | .00 | -.11 |
| L.C. | -.08 | .04 | .10 | .19 | .09 | -.01 |
| L.R. | .27 | .17 | .09 | .09 | .14 | .10 |
| W.L. | .07 | .62 | -.11 | -.10 | .03 | .45 |
| C.H.L. | .09 | .24 | .22 | -.05 | .06 | -.03 |
| C.H.S. | .02 | .00 | -.14 | -.13 | .09 | .15 |
| W.H.L. | .09 | .15 | .11 | -.03 | .13 | .10 |
| L.H.L. | .27 | -.01 | .26 | .18 | .03 | .00 |

Correlation of .15 is significant at .05 level.
Correlation of .20 is significant at .01 level.

CODE:

D.H.-----Depth of heart

L.F.-----Length right forecannon

C.F.-----Circumference right forecannon

L.B.-----Length body

L.C.-----Length coupling

L.R.-----Length rump

W.L.-----Width second lumbar

C.H.L.---Circumference hind leg

C.H.S.---Circumference hind stifle

W.H.L.---Width hind leg

L.H.L.---Length from hook to leg insertion

Length of right forecannon of the carcass was highly significantly correlated with width of the second lumbar, .62, in the labm. It was also significantly related to length of forecannon, .29; length of body, .19; circumference of hind leg, .24; and width of hind leg, .15, in the lamb. These correlations indicated that lambs which were longer in the forecannon were larger framed and had larger live measurements.

Circumference of right forecannon of the carcass was significantly correlated with circumference of the forecannon of the lamb, .62; length of body, .24; circumference of hind leg, .22; and length from hook to leg muscle insertion, .26.

Length of body, in carcass, was significantly related to length of coupling .19. Width of loin in the carcass was significantly correlated with width of loin in the lamb, .45.

The relatively low magnitude of these correlations indicated that, in general, measurements taken on the lambs were not accurate indicators of the same measurements on the carcasses.

## Relationship Between Carcass Measurements and Carcass Characteristics

The measurements taken on the carcass were more highly correlated with carcass characteristics than were the measurements taken on the lamb. Correlation coefficients between carcass measurements and carcass characteristics are presented in Table 7.

Depth of heart in the carcass was significantly correlated with all carcass characteristics studied except carcass grade. Depth of heart was highly significantly correlated with all of the wholesale cuts except weight of loin for which the correlation was only significant.

CODE
(Table 7)

C.G.-----Carcass grade

Wt.B.----Weight of breast

Wt.S.----Weight of shoulder

Wt. R.---Weight of rack

Wt.L.----Weight of loin

Wt.Le.---Weight of leg

S.W.C.---Sum wholesale cuts

Le.A.-----Loin-eye area

B.F.------Back fat

L.R.------Lean in rack

F.R.------Fat in rack

B.R.------Bone in rack

D.H.-----Depth heart

L.F.-----Length right forecannon

C.F.-----Circumference right forecannon

L.B.------Length body

W.H.L.---Width hind leg

W.L.-----Width second lumbar vertebra

Table 7. Correlation coefficients between carcass measurements and carcass characteristics.

| Characteristics | D.H. | L.F. | C.F. | L.B. | W.H.L. | W.L. |
|---|---|---|---|---|---|---|
| | | | Measurements | | | |
| C.G. | -.02 | -.13 | -.16 | -.12 | .20 | .42 |
| Wt.B. | .28 | .02 | .08 | .18 | .26 | .35 |
| Wt.S. | .33 | .23 | .13 | .14 | .28 | .16 |
| Wt.R. | .31 | -.09 | .19 | .08 | .25 | .44 |
| Wt.L. | .15 | -.03 | -.10 | .07 | .14 | .55 |
| Wt.Le. | .30 | .11 | .22 | -.02 | .40 | .30 |
| S.W.C. | .33 | .07 | .13 | .07 | .30 | .48 |
| Le.A. | .17 | .13 | .19 | .01 | .19 | .06 |
| B.F. | .19 | .05 | .14 | .06 | .08 | .23 |
| L.R. | .24 | .00 | .29 | .03 | .25 | .12 |
| F.R. | .24 | -.18 | .02 | .05 | .19 | .55 |
| B.R. | .37 | .17 | .42 | .14 | .15 | -.02 |

Correlation of .15 is significant at .05 level.

Correlation of .20 is significant at .01 level.

Length of right forecannon was significantly correlated with weight of shoulder, .23. Grams of fat and grams of bone in the rack were also significantly correlated with length of forecannon, -.18 and .17, respectively. The longer legged lamb had a longer larger skeletal frame; thus the positive relationship between weight of shoulder and grams of bone in the rack.

Circumference of right forecannon in the carcass was significantly correlated with carcass grade, -.16 and so was the circumference of forecannon in the lamb, r = .29. Length of forecannon was also significantly related to weight of the leg, r = .22, grams of lean in the rack, r = .29, and grams of bone in the rack, r = .42. The larger boned lambs were heavier muscled as indicated by increased weight of leg and of lean in the rack.

Length of body was neither significantly related with carcass characteristics nor with lamb measurements.

Width of hind leg was the best indicator of weight of leg and loin-eye area. These correlations were, .40 and .19 between weight of leg and loin-eye area and width of hind leg. Width of hind leg was significantly correlated with carcass grade, .20. Much emphasis is placed on thickness and plumpness of leg as the lamb hangs on the rail in determining a conformation grade for the carcass. Width of hind leg was also significantly correlated with weight of breast, .26; shoulder, .28; rack, .25; and total wholesale cuts, .30. Grams of lean, fat, and bone in the rack were significantly related to width of hind leg; the correlations being .25, .19 and .15, respectively.

Width of the loin in the carcass was more highly correlated with

carcass traits that indicated fat in the carcass than with any other carcass traits: carcass grade, .42; weight of breast, .35; weight of rack, .44; and weight of loin .55. Back fat thickness and grams of fat in the rack were also significantly related to width of loin, .23 and .55, respectively.

The most useful lamb or carcass measurements as indicators of lean, fat and bone in the carcass were: width of loin as an indicator of fat, circumference of forecannon in the lamb and the carcass was the best indicator of the amount of bone; and length of rump in the live lamb and width of hind leg in the carcass were the best indicators of lean in the carcass.

## Relationship Between Carcass Characteristics

Cold dressed weight was significantly correlated with several of the carcass characteristics such as feathering, .20, and marbling, .15. The correlation coefficients between carcass characteristics are presented in Table 8. The correlation between cold carcass weight and grade was .28. Cold carcass weight was highly significantly correlated with the weight of each wholesale cut except weight of breast. This would be expected since each wholesale cut helps make up carcass weight. Weight of loin had the highest correlation of .65, with cold dressed weight. A significant relationship, $r = .18$, was found between grams of fat in the rack and cold dressed weight. Weight of bone in the rack was significantly correlated, -.15, with cold dressed weight.

Feathering was significantly correlated with actual marbling in the cross-section of the longissimus dorsi at the twelfth rib, .33. Though

CODE (Table 8)

C.W.——Cold dress weight

Fea.——Feathering

Mar.——Marbling

Fir.——Firmness

Col.——Color of lean

C.G.——Carcass grade

Wt.B.——Weight of breast

Wt.S.——Weight of shoulder

Wt.R.——Weight of rack

Wt. L.——Weight of loin

Wt.Le.——Weight of leg

S.W.C.——Sum wholesale cuts

Le.A.——Loin-eye area

B.F.——Back fat thickness

L.R.——Lean in rack

F.R.——Fat in rack

B.R.——Bone in rack

% F.I.——Per cent fat in intercostal muscles

% F.L.D.——Per cent fat in longissimus dorsi muscle

Table 8. Weighted average correlation coefficients between carcass characteristics.

| | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| C.W. (1) | .20 | .15 | .17 | | .28 | | .59 | .58 | .65 | .63 | | | .01 | .03 | .18 | -.15 | .01 | .16 |
| Fea. (2) | | .33 | | .21 | .72 | .20 | .03 | .13 | .21 | .16 | | | .01 | .03 | .18 | -.15 | -.07 | .22 |
| Mar. (3) | | | | .20 | .37 | .16 | .10 | .11 | | | | -.09 | | | .21 | -.13 | -.01 | .49 |
| Fir. (4) | | | | | | .30 | | | | .16 | | -.11 | | | .16 | | -.37 | .33 |
| Col. (5) | | | | | | .10 | | .12 | | .14 | | | | -.08 | | .15 | -.32 | .24 |
| C.G. (6) | | | | | | .20 | .11 | .16 | .30 | .19 | .24 | | .13 | -.07 | .23 | -.20 | .36 | -.14 |
| Wt.B. (7) | | | | | | | .26 | .40 | .33 | .41 | .58 | .23 | .26 | .24 | .40 | .15 | .25 | .03 |
| Wt.S. (8) | | | | | | | | .30 | .24 | .52 | .66 | .28 | .22 | .16 | .25 | .15 | .11 | .19 |
| Wt.R. (9) | | | | | | | | | .48 | .32 | .65 | .18 | .41 | .65 | .84 | .49 | .10 | .26 |
| Wt.L. (10) | | | | | | | | | | .28 | .62 | .12 | .47 | | .61 | | .21 | .12 |
| Wt.Le. (11) | | | | | | | | | | | .72 | .39 | .06 | .39 | .16 | .25 | .01 | -.18 |
| S.W.C. (12) | | | | | | | | | | | | .35 | .32 | .41 | .58 | .30 | | |
| Le.A. (13) | | | | | | | | | | | | | .10 | .40 | | .16 | .02 | .18 |
| B.F. (14) | | | | | | | | | | | | | | | .56 | -.09 | .20 | .14 |
| L.R. (15) | | | | | | | | | | | | | | | .20 | .67 | -.22 | -.12 |
| F.R. (16) | | | | | | | | | | | | | | | | | .26 | .30 |
| % F.I. (17) | | | | | | | | | | | | | | | | | -.29 | -.11 |
| % F.D.L. (18) | | | | | | | | | | | | | | | | | | .15 |

Correlation of .15 is significant at .05 level. Correlation of .20 is significant at .01 level.

this correlation was significant, it was small enough to indicate that actual marbling can not be accurately estimated from the amount of feathering in the carcass. Color of lean was also significantly correlated with feathering, .21. Amount of feathering was highly significantly correlated with carcass grade, .72. Feathering is considered a quality factor and, as indicated by the correlation, considerable weight was placed on the amount of feathering when determining the grade for the carcass. Feathering was significantly related to weight of breast, r = .20, and weight of loin, r = .21, both of which are made up of considerable fat. Feathering was also significantly correlated with grams of fat in the rack .18 and grams of bone in the rack, -.15. Also, the per cent fat in the longissimus dorsi was significantly related to featering, r = .22.

Actual marbling score, which is another indicator of quality, was significantly correlated with carcass grade, .37; grams of fat in rack, .21, and with per cent fat in longissimus dorsi, .49.

These two quality factors, marbling and feathering, which are significantly related to carcass grade and fat factors were positively related to market age in the lamb. Therefore, it appears that the producer that does the best job of getting his lambs to market at an early age will sell lambs yielding lower carcass grades due to the lack of quality factors in younger lambs.

Carcass grade was more highly correlated with weight of breast, .20, and weight of loin, .30, than with other wholesale cuts. Grams of fat in the rack and per cent fat in the intercostal muscles were significantly correlated with carcass grade, .23 and .36, respectively. Carcass grade was non-significantly related to weight of shoulder, r = .11, but was

significantly correlated with weight of leg, .19. The correlations presented in Table 8 indicate that all of the factors indicating fat in the carcass were positively related with carcass grade and all factors indicating lean were either non-significant or negatively correlated with carcass grade. This is in agreement with Matthews (1959).

Weights of the five wholesale cuts were all significantly related with each other. The highest significant correlation was .52 between weight of shoulder and weight of leg. Weight of leg was more highly correlated with loin-eye area, .39, than any of the other cuts. Loin-eye area was significantly related to weight of breast, r = .23, weight of shoulder, r = .28, weight of rack, r = .18 and sum of the five wholesale cuts, r = .35.

Weight of loin was more highly correlated with back fat thickness, .47. Back fat thickness was significantly related to weight of the breast, r = .26, weight of the shoulder r = .22, weight of the rack, r = .41, and was non-significantly related to weight of leg, r = .06.

Weight of leg was significantly correlated with grams of lean in the rack, .39 and with total weight of the rack .65. Lean in the rack was significantly related to weight of breast, r = .24 and weight of shoulder.

Weights of breast and loin were significantly correlated with grams of fat in the rack, .40 and .58, respectively. Correlations between the amount of fat in the rack and weight of shoulder and leg were only .25 and .16, respectively. Correlations between weight of bone in the rack and weight of the leg, breast and shoulder were .25, .15, and .15, respectively. Weight of the loin was non-significantly related to grams of bone in the rack.

Weights of breast and loin were the only traits significantly related to per cent fat in the intercostal muscle; correlations of .25 and .21, respectively. Weights of the shoulder and rack were the only ones significantly associated with per cent fat in the longissimus dorsi, correlations of .19 and .26, respectively.

These data indicated that weights of the leg and of the shoulder were positively related to characteristics indicating leanness or muscling and negatively or non-significantly related to characteristics positively associated with fat. Weights of the breast and of the loin were positively associated with characteristics associated with fat. This was in agreement with Hankins and Titos (1939).

Loin-eye area was significantly related to grams of lean in the rack, $r = .40$, and grams of bone in the rack, $r = .16$. Back fat thickness was significantly related to grams of fat in the rack .56 and per cent fat in the intercostal muscles, .20.

Grams of lean, fat and bone in the rack according to Hankins (1947) are the best criteria for estimating the same components in the remaining portions of the carcass.

## Sire Effect and Heritability Estimates

To efficiently use the data presented thus far in a selection program the producer should know what effect the sire has on these traits and how highly heritable these traits may be. Variance in each traist was analyzed for sire effects and heritability was estimated for each trait by quadrupling the paternal half-sib correlation.

Sire effects were highly significant for the following traits: birth

weight, average daily gain, market age, length of rump, length of right forecannon, feathering, degree of marbling, and weight of loin. The sire differences in rib-eye area were significant. Ross et al. (1960) found highly significant differences for untrimmed leg and shoulder and significant differences for birth weight, weaning weight and wool weight. Sire differences in rate of gain were not significant.

The heritability estimates reported in Table 9 (all of those of zero and above are reported) are subject to large sampling errors because of the limited number of sire groups. Of all wholesale cuts, the highest estimate of heritability was for weight of loin, .46. Estimates for shoulder and breast were .08 and .02, respectively.

Production traits were more highly heritable, in general, than measurements or carcass characteristics. The estimates for birth weight, average daily gain and market age were .60, .54, and .53, respectively.

Heritability estimates of measurements taken on the lamb were length of rump, .50, and length of right forecannon, .51. If these are near the true average heritability value for these traits, the producer should make appreciable improvement in these traits by emphasizing them in his selection. These two measurements are important because they are closely associated with leanness and bone characteristics in the carcass.

The estimate for length of body was .09. The heritability estimate for feathering was higher than that for any of the carcass traits, .57. Heritability of grams of lean and bone in the rack were estimated to be .16 and .10 respectively. Firmness and marbling were 14 and 39 per cent heritable.

Table 9. Heritability estimates based on paternal half-sib correlations.

| | Heritability estimates |
|---|---|
| Weight of shoulder | .08 |
| Birth weight | .60 |
| Weight of loin | .46 |
| Weight of breast | .02 |
| Grams of lean in rack | .16 |
| Grams of bone in rack | .10 |
| Feathering | .57 |
| Firmness of carcass | .14 |
| Marbling | .39 |
| Average daily gain | .54 |
| Market age | .53 |
| Back fat thickness | .21 |
| Loin-eye area | .39 |
| Length of body | .09 |
| Length of rump | .50 |
| Length of right forecannon | .51 |

# SUMMARY

The 176 crossbred lambs used in this study for two consecutive years were produced by mating 100 western ewes with ten different Hampshire rams each year for two consecutive years. The 19 different rams which sired lambs were scored by a committee and correlations were calculated between ram scores and lamb production and carcass traits. All lambs were sheared, measurements were taken, and they were slaughtered when they weighed 95 to 100 pounds. Simple correlation coefficients were obtained between all lamb and carcass traits studied.

The relationships between ram scores indicated that in selecting for general type most emphasis was placed on muscling, size of bone, size of leg and weight of ram. Size of rear leg was most closely correlated with estimated muscling, and shorter legged rams were believed to be heavier boned. Weight of ram was significantly related with depth of probe of longissimus dorsi muscle.

Only a few ram traits were significantly related with lamb carcass and production traits. Shorter legged rams sired lambs with greater width of loin-eye, $r = .48$; depth loin-eye, $r = -.50$; and larger loin-eye areas, $r = .35$. Depth of the longissimus dorsi probe in the ram was negatively related to market age of his lambs, $r = -.60$, and lamb carcass grade $r = -.59$.

The relationship between lamb production traits and their carcass characteristics indicated that lambs heavier at birth gained faster and reached market weight at an earlier age. The carcasses from younger lambs contained less feathering and marbling and consequently were lower grading carcasses. The rate of gain in lambs was positively related to carcass

traits indicating leanness and bone, and negatively related to carcass traits indicating fatness, denoting that up to a weight of 100 pounds, gain is primarily due to growth rather than the production of fat.

Few correlations between lamb measurements and carcass characteristics, even those that were statistically significant, were of sufficient magnitude to be effectively employed in a selection program. However, length of rump was significantly correlated with weight of leg, .51, and weight of leg was significantly correlated with loin-eye area, .39, and grams of lean in the rack, .39. Width at the second lumbar vertebra was more closely correlated to carcass characteristics indicating fatness.

Measurements taken on the lambs were not accurate indicators of the same measurements on the carcass. The most useful lamb or carcass measurements that could be used as an indicator of lean, fat or bone in the carcass were: width of loin in the lamb and carcass as an indicator of fat, circumference of forecannon in the lamb and carcass as an indicator of the amount of bone and length of rump in the lamb and width of hind leg in the carcass were the best indicators of lean in the carcass.

Feathering and marbling were significantly related to fat factors and carcass grade which were positively related to market age of the lambs. Carcass grade was positively related with fat factors in the carcass and either non-significantly or negatively correlated with factors indicating leanness in the carcass. Weights of leg and shoulder were positively related to increased leanness in the carcass and weights of the loin, rack and breast were positively related to increased fatness in the carcass.

Sire effects were highly significant for birth weight, average daily gain, length of rump and forecannon, feathering and marbling score, and

weight of loin. Gnerally, production traits were more highly heritable than lamb measurements or carcass characteristics, except length of fore-cannon, .51, and length of rump, .50 in the lamb, and feathering, .57, and marbling, .39 in the carcass.

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HERITABILITIES AND CORRELATIONS BETWEEN CARCASS AND LIVE ANIMAL TRAITS IN SHEEP

by

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The relationship between various live animal measurements and carcass characteristics were studied by using 176 crossbred lambs produced by 19 different sires. Sire effects and heritability estimates (paternal half-sib correlations) were computed for all traits studied. Shorter legged rams sired lambs with larger loin-eye areas. Depth of loin probe in the ram was negatively correlated with market age, -.60, and carcass grade of his lambs, -.50. Lambs heavier at birth gained faster and produced carcasses with less feathering and marbling; consequently lower grading carcasses. Weight of leg in the lamb was significantly correlated with length of rump, .51, loin-eye area, .39, and grams of lean in rack, .39. Width of loin was significantly correlated with weight of rack, .30, weight of loin, .45, and grams of fat in rack, .34. Circumference of forecannon was significantly correlated with grams of bone in the rack, .39. Feathering and marbling were significantly related to fat factors and carcass grade which were positively related to market age of lamb. Sire effects were highly significant for birth weight, average daily gain, length of rump and forecannon, feathering and marbling score, and weight of loin.

Generally, production traits were more highly heritable than lamb measurements or carcass characteristics, except length of forecannon, .51, and length of rump, .50, in the lamb, and feathering, .57 and marbling, .39 in the carcass.